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A MULTI-SHEAR APPARATUS

B. Gorski
Rock Mechanics Laboratory

MAY 1984

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16 pp

MINERALS RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT MRP/MRL 84-44(TR)

SEP 24 1984

MICROMEDIA

A MULTI-SHEAR APPARATUS

by

B. GORSKI*

ABSTRACT

A multi-shear apparatus has been developed by the Rock Mechanics Laboratory. The apparatus described in this report has been used successfully to determine the basic friction angle of rock core surfaces.

*Senior Rock Mechanics Technologist, Rock Mechanics Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

APPAREIL DE CISAILLEMENT MULTIPLE

par

B. GORSKI*

RÉSUMÉ

Un appareil de cisaillement multiple a été mis au point par le Laboratoire de la mécanique des roches. L'appareil décrit dans ce rapport a servi avec succès pour déterminer l'angle de frottement de base de surfaces de carottes de roche.

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*Technologue supérieur de la mécanique des roches, Laboratoire de la mécanique des roches, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa.

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INTRODUCTION

Patton [1] and Barton [2] have studied the effective friction angle of rock joints. They conclude that this angle is comprised of a basic friction angle and a surface roughness angle. Barton [3] has described the basic friction angle as the "value of arctan (τ/σ_n) obtained from residual shear tests on flat, unweathered rock surfaces which are normally prepared by sawing, but which can conveniently be sand-blasted between tests".

An alternative method to measure the basic friction angle, suggested by Stimpson [4], uses rock cores and a tilt table. On the tilt table, while in horizontal position, two pieces of core are placed in contact with one another. A third core is placed on top of the other two. The bottom two cores are restrained from sliding. The base is rotated slowly until sliding of the upper core occurs [Fig. 1]. The angle of tilt at the point of sliding is measured to $\pm 0.5°$ and recorded.

The Stimpson method has been investigated by the Rock Mechanics Laboratory (RML) by using the apparatus shown in Fig. 1. The test results indicate that the method can be used for smooth, dry, homogeneous rock core surfaces. The normal load is calculated from the weight of the sliding core. The angle of tilt and the normal load values are used to derive the friction angle.

A multi-shear apparatus [Fig. 2] has been developed to further shear research by RML. The apparatus is used to measure the basic friction angle of intact rock core surfaces at various normal loads. The apparatus incorporates a unique hydraulic loading system for applying normal load.

The multi-shear apparatus has been used successfully [5] in determining the coefficient of sliding friction of several rock types.

Rock core samples having mechanically prepared interlocking surface irregularities are being considered for future testing using the multi-shear apparatus.

The design and operation of the multi-shear apparatus is described in this report including relevant aspects of sample preparation.

THEORY OF OPERATION

The operation of the multi-shear apparatus is based on the law of friction [6] that states "the friction force is not dependent upon the areas

of the surfaces in contact". Figure 3 shows the test arrangement of rock cores. A known load is applied to the outer three cores. This loading arrangement transmits three equal line loads normal to the center core. The normal load is maintained hydraulically while the center core is displaced axially.

The test, results in a value of the coefficient of static friction stated as follows:

$$\mu = \frac{F}{N} = \tan \phi$$

μ = coefficient of static friction

F = axial load (limiting friction force when motion impends)

N = normal load applied by outer three core when motion is impending

$\tan \phi$ = basic angle of friction

Values of the coefficient of sliding friction at low velocities for dry surfaces are about equal to those for static friction.

DESIGN CONSIDERATIONS

The design of the component parts of the multi-shear apparatus is governed by the following considerations:

1. The maximum axial loading capacity of the apparatus is 10 kN.
2. An anticipated maximum axial displacement of 25 mm is expected.
3. The maximum normal loading capacity of the apparatus is 2.5 kN.
4. An anticipated maximum normal displacement of 13 mm is expected.
5. An existing confinement pressure panel is used for applying normal loads hydraulically.
6. An existing Tinius Olsen press is used for applying axial loads.
7. A retrofitted existing machine lathe is used for grooving or surface finishing of rock core specimens.
8. 'BX' size samples are to be tested.

The multi-shear apparatus [Fig. 4] is machined from mild steel to the following dimensions:

1. Outside diameter of 300 mm.
2. Inside diameter of 130 mm.
3. 50 mm thick.

4. Three slots spaced 120° along the inside diameter having dimensions 40 mm wide, 35 mm deep to accommodate 'V' blocks.
5. 9 mm diameter thru holes to accommodate hydraulic pistons at slot locations.
6. Three 12 mm diameter adjusting leg screw holes.

The 'V' blocks have seats to accept the outer cores. The seats resist axial core displacement but do allow movement in the normal direction. The lower contact surfaces of the seats are greased.

Axial displacement of the central core is measured using a linear variable differential transformer (LVDT). The LVDT is held by an 'arm' clamped to the shear loading platen [Fig. 2].

Shear load is monitored using a strain-gauged ring load cell [Fig. 2]. Shear load versus axial displacement of the central core is plotted on an X, Y_1, Y_2 recorder.

A novel method was used to monitor normal displacement. Figure 6 depicts this method. Trigonometry can be used to derive displacement as follows:

$$X = \frac{LVDT}{3} \text{ Cos } 30°$$

X = average displacement in the normal direction at any one contact line (mm)

LVDT = linear variable differential transformer reading

$\frac{LVDT}{3}$ = average voltage output converted to mm.

Shear load versus normal displacement is plotted on an X, Y_1, Y_2 recorder.

An existing confinement pressure panel is used to apply hydraulic pressure to the multi-shear pistons. The ring load cell was used to calibrate the piston loading mechanism as a function of the applied hydraulic pressure.

SAMPLE TEST REQUIREMENTS

To date, only rock cores having smooth, homogeneous surfaces have been tested. The only other requirements have been that the rock cores be end cut to specified lengths and oven dried prior to testing. However, consideration is being given to testing rock cores having surface irregularities. The irregularities or contours, can be introduced mechanically using a machinist's lathe [Fig. 5]. These contours could be prepared as follows:

1. Lathing a contour on a grinding wheel using a diamond dressing bit.
2. Lathing the mating contour on another grinding wheel using a diamond dressing bit.
3. Using the above grinding wheels on a power grinder attached to the lathe tool post.
4. With a rock core mounted in the lathe the contour is ground into the rock surface.

MULTI-SHEAR TEST OPERATION

Figure 2 shows the multi-shear apparatus set-up for a test. With four cores in place a normal hydraulic load is applied to the 'V' block pistons using the confinement pressure panel. The central core is seated on a spacer block prior to normal load application. The spacer block is removed after normal load application. The LVDT platen and ring load cell are placed on top of the center core. The center core is axially loaded using the compression machine. Figures 7a) and 7b) depict idealized plots of shear load versus shear displacement. The stepped plot depicted in Figure 7a) is the result obtained by incrementing the normal load on one set of rock core surfaces. Figure 7b) depicts the results obtained by applying increments of normal load to different sets of rock core surfaces. The term "rock core surface" is a misnomer as used here-in. In effect, it is three rock contact lines that experience shear during the test.

CONCLUSIONS

The basic angle of friction of several rock core surfaces has been calculated based on multi-shear test results. Repeatability of test results has been established using the multi-shear apparatus.

The multi-shear apparatus is suited to the study of the variation of the frictional properties of rock core surfaces with displacement. Furthermore, incremental measurements may be made for purposes of establishing the variation of shear stress with normal stress of rock core surfaces.

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6. Jensen, A. and Chenoweth, H.H. "Applied engineering mechanics"; Second Edition, McGraw-Hill Book Co., USA, p 147.

Fig. 1 - Tilt table

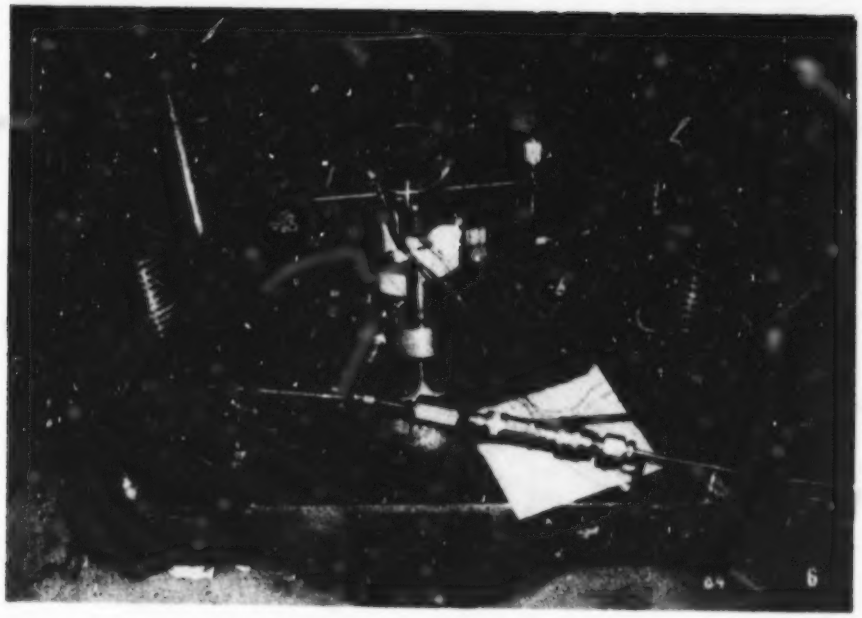


Fig. 2 - Multi-shear apparatus

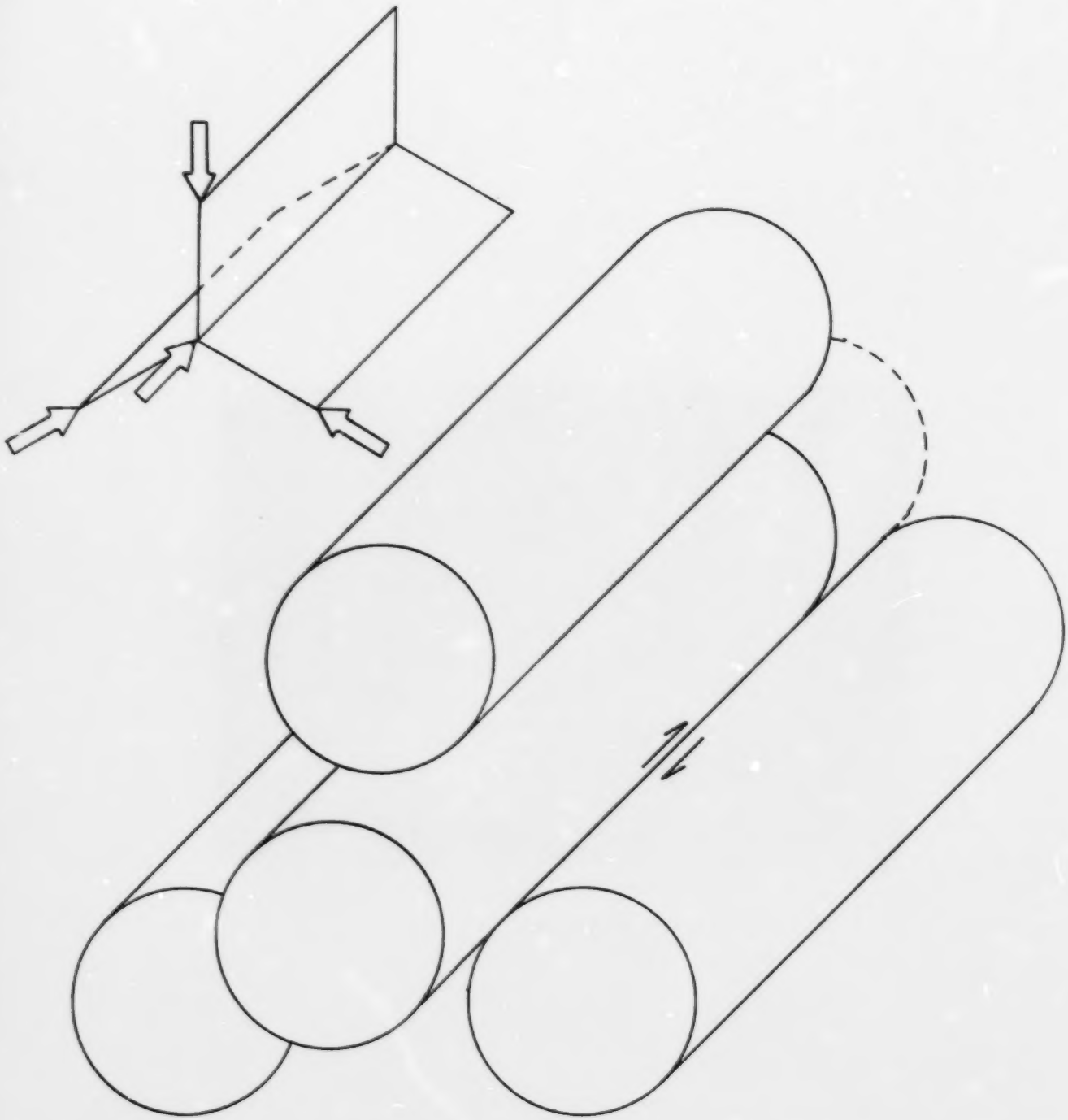
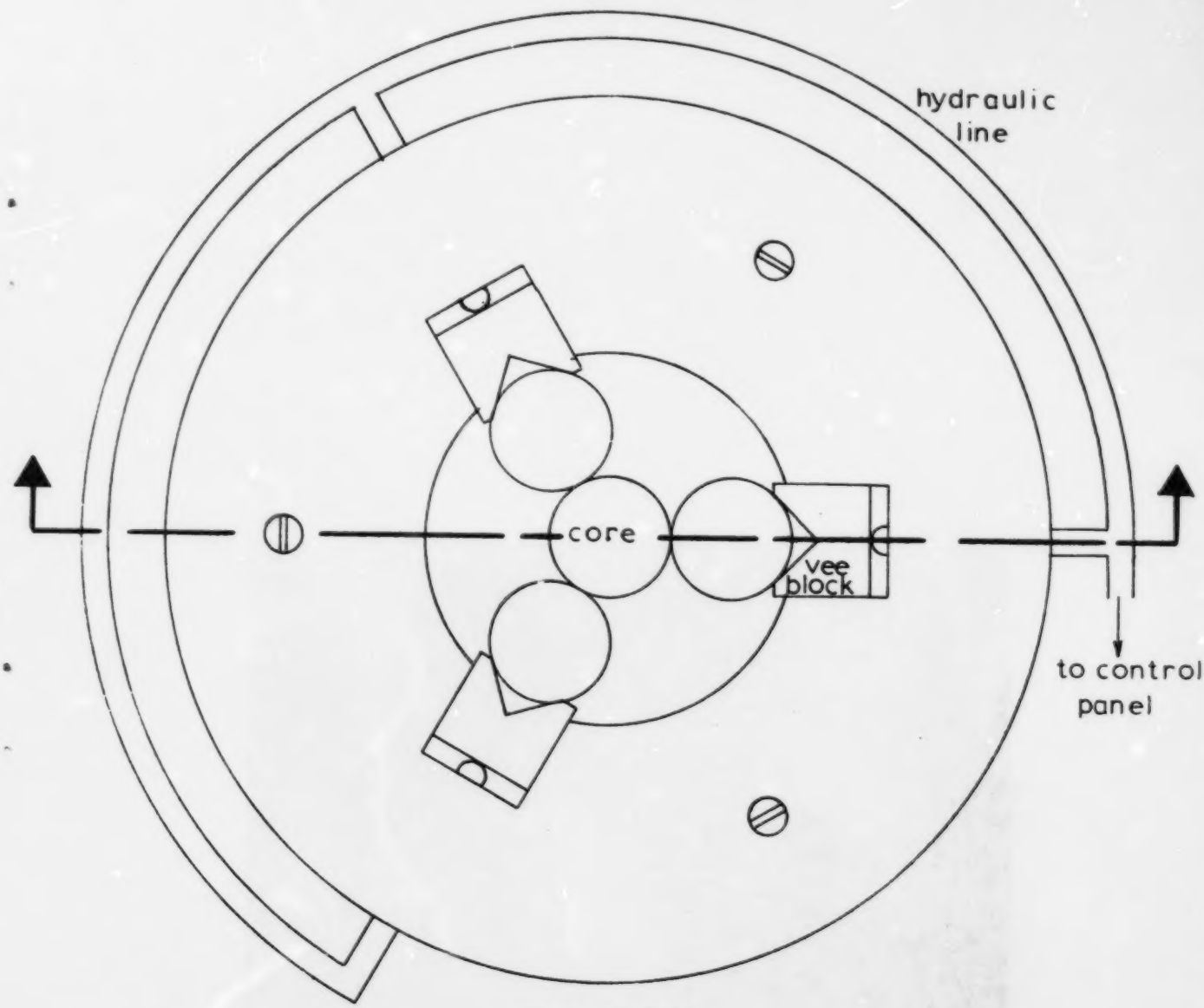
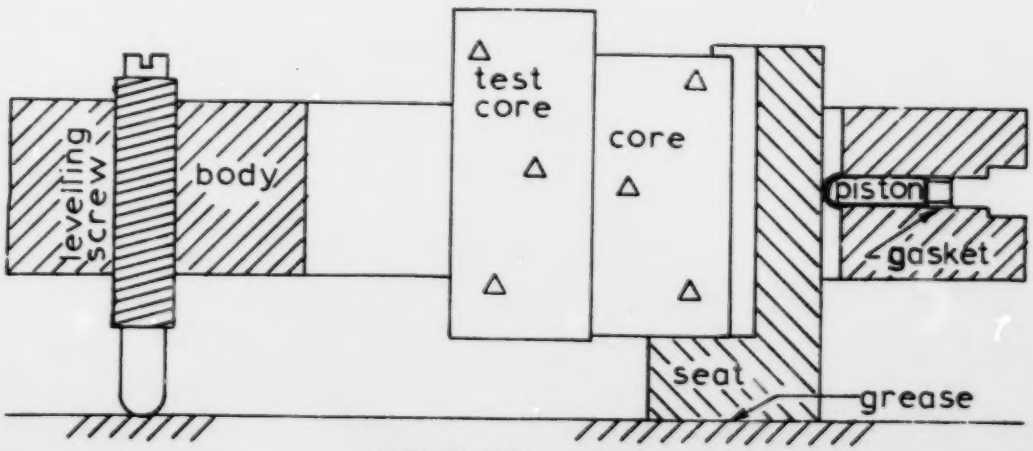


Fig. 3 - Rock core arrangement



TOP VIEW



SECTION VIEW

Fig. 4 - Multi-shear apparatus details

Fig. 5 - Rock surface prep

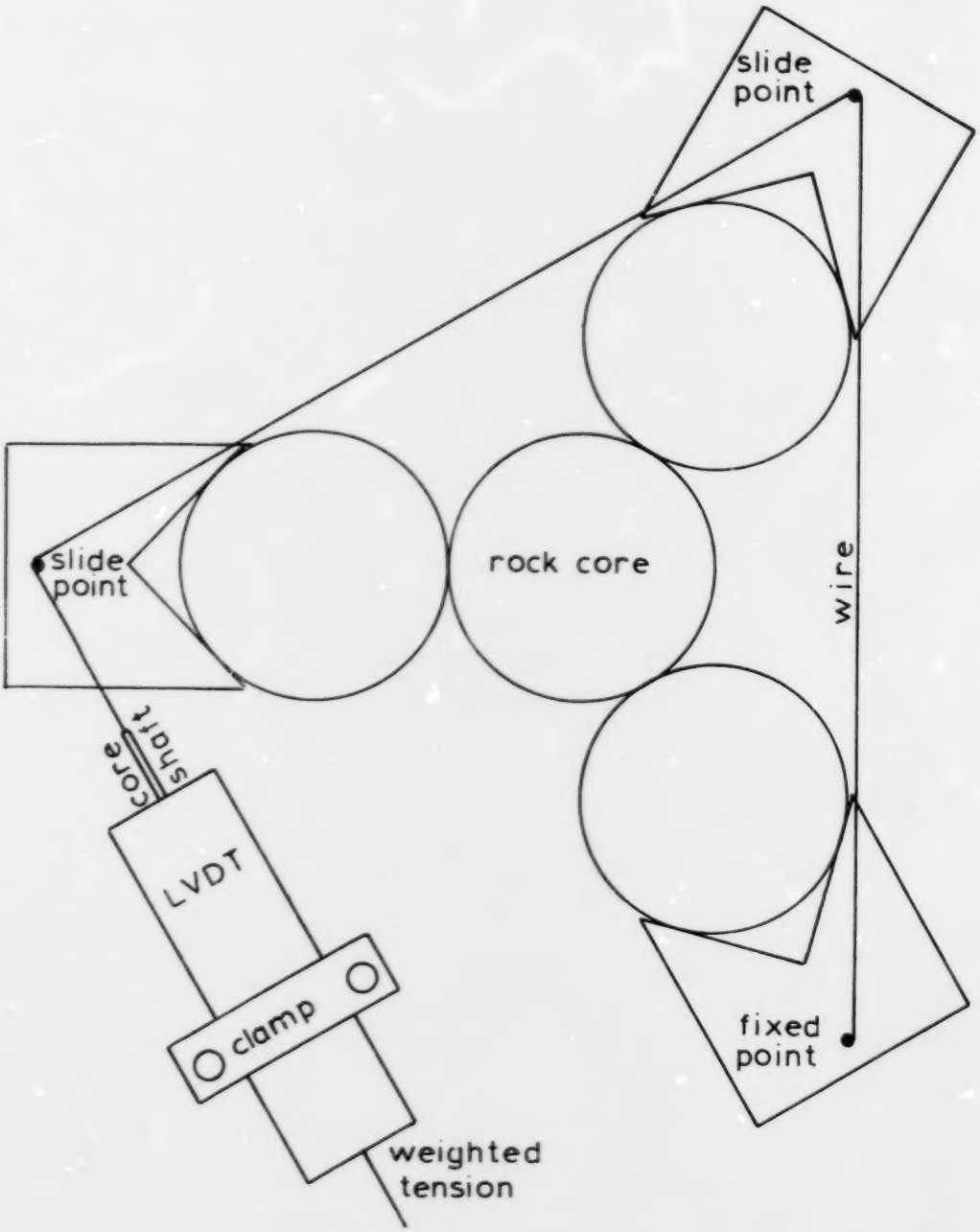


Fig. 6 - Normal displacement measurement

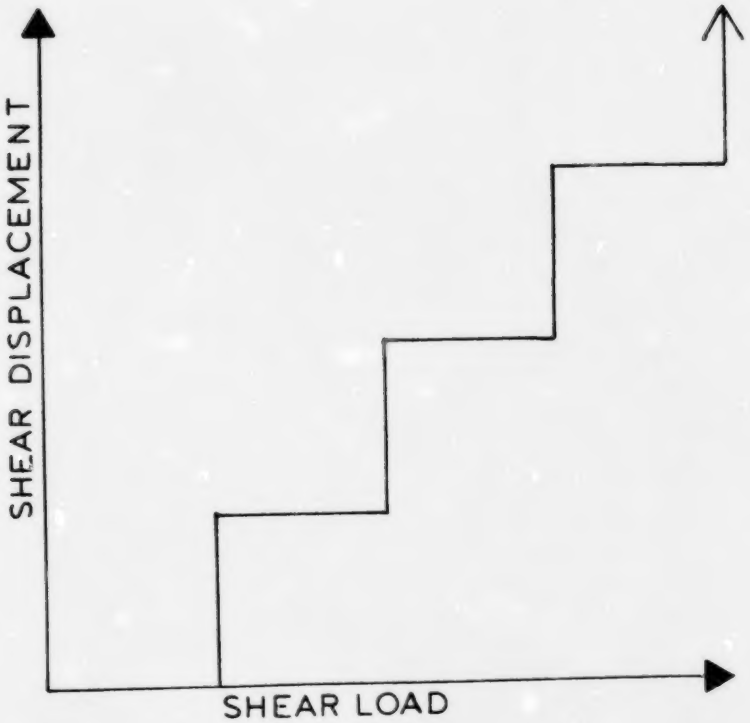


Fig. 7 a) - Method 'A' shear test

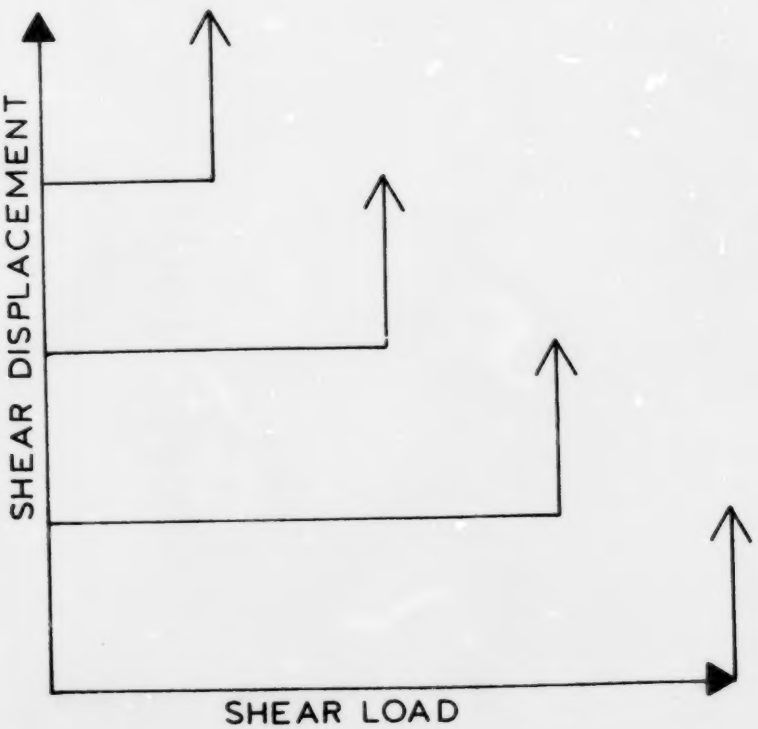


Fig. 7 b) - Method 'B' shear test